Fermilab

Particle Physics Division

12-01-01

Mechanical Department Engineering Note

Number: MD-Eng-130 **Date:** 5/15/2007 **Lifting Device Number:** 163

Project: Lab 7

Project Internal Reference:

Title: Lifting device for the bottom collar of the Large Bell Jar vacuum deposition system

Author(s): Matt Slabaugh

Reviewer(s): Ang Lee

Key Words: Large Bell Jar, Vacuum, Lifting Fixture

Abstract/Summary: This device is currently in service at Lab 7. The Large Bell Jar consists of three main components- the large "bell" supported by two collars (rings), middle and lower. The bell is lifted via an eyebolt, and the middle collar is lifted with straps on fitting protrusions. The bottom, supporting collar must seal against the vacuum table. To do this a lifting device was put into service for ease of installation. This note is to bring the lifting device into conformance of a department mandate to have engineering documentation for all in-house fabricated tools.

Applicable Codes: ASME B30.20-2003 Below-the-Hook Lifting Devices

5022TA

BELOW-THE-HOOK LIFTING DEVICE
Engineering Note Cover Page

Lifting Device Numbers: **163**

FNAL Site No/ Lab 7 (If applicable) Div. Specific No. _____ (If applicable) Asset No. _____ (If applicable)

ASME B30.20 Group: (check one)
- [√] Group I Structural and Mechanical Lifting Devices
- [ ] Group II Vacuum Lifting Devices
- [ ] Group III Magnets, Close Proximity Operated
- [ ] Group IV Magnets, Remote Operated

Device Name or Description: Lifting device for the bottom collar of the Large Bell Jar vacuum deposition system

Device was (check all applicable)
- [ ] Purchased from a Commercial Lifting Device Manufacturer. Mfg Name _____
- [√] Designed and Built at Fermilab
- [ ] Designed by Fermilab and Built by a Vendor. Assy drawing number _____
- [ ] Provided by a User or other Laboratory
- [ ] Other: Describe _____

Engineering Note Prepared by M. Slabaugh Date 5/15/2007

Engineering Note Reviewed by Ang Lee Date 6/20/2007

Lifting Device Data:

Capacity 130 Lbs

Fixture Weight 20 Lbs

Service: [√] normal [ ] heavy [ ] severe (refer to B30.20 for definitions)

Duty Cycle _____ 8, 16 or 24 hour rating (applicable to groups III, and IV)

Inspections Frequency _____

Rated Load Test by FNAL (if applicable) Date 7/19/2007 Load 165 Lbs

[ ] Check if Load Test was by Vendor and attach the certificate

Satisfactory Load Test Witnessed by: Andrew Lathrop

Signature (of Load Test Witness) _____

Notes or Special Information:

This device is used in conjunction with a 1-ton capacity gantry crane. It is used to lift the bottom collar of the Large Bell Jar vacuum deposition system. The collar weighs 130 Lbs. This device shall not be used to lift any other object without further engineering analysis.

Aluminum beam

Figure 1 below illustrates the LBJ lifting device. The beam is 6061 T6 aluminum, 6x3.63lbs C-channel 40" in length. A 3/8" eyebolt is used as the hook pick point (center hole) and six (6) 3/8" stainless bolts are used to clamp the blocks on the ends.

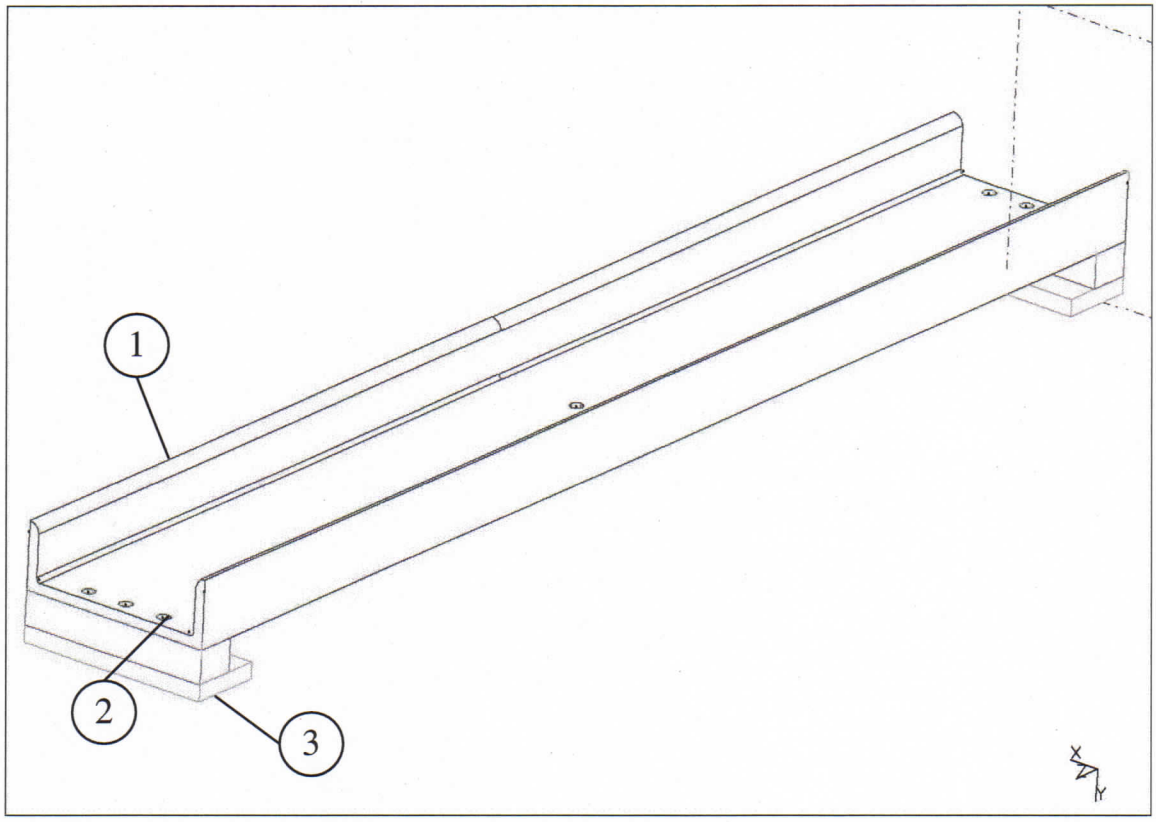

Figure 1. LBJ lifting device. Composed of **(1)** 40" Aluminum channel, **(2)** 3/8" 304 Stainless bolt, and **(3)** 2 ¼"x ½" x 6" Aluminum block

Item (1) Aluminum channel

Figure 2 shows a beam simply loaded on each end, fixed in the center. The analysis was run with a load 25% greater than that of the lower collar, 162 Lbs as opposed to 130 lbs. Figure 3. illustrates the result of the analysis. The maximum stress seen by the beam is 2480 psi, the max allowable stress is 12,000 psi.

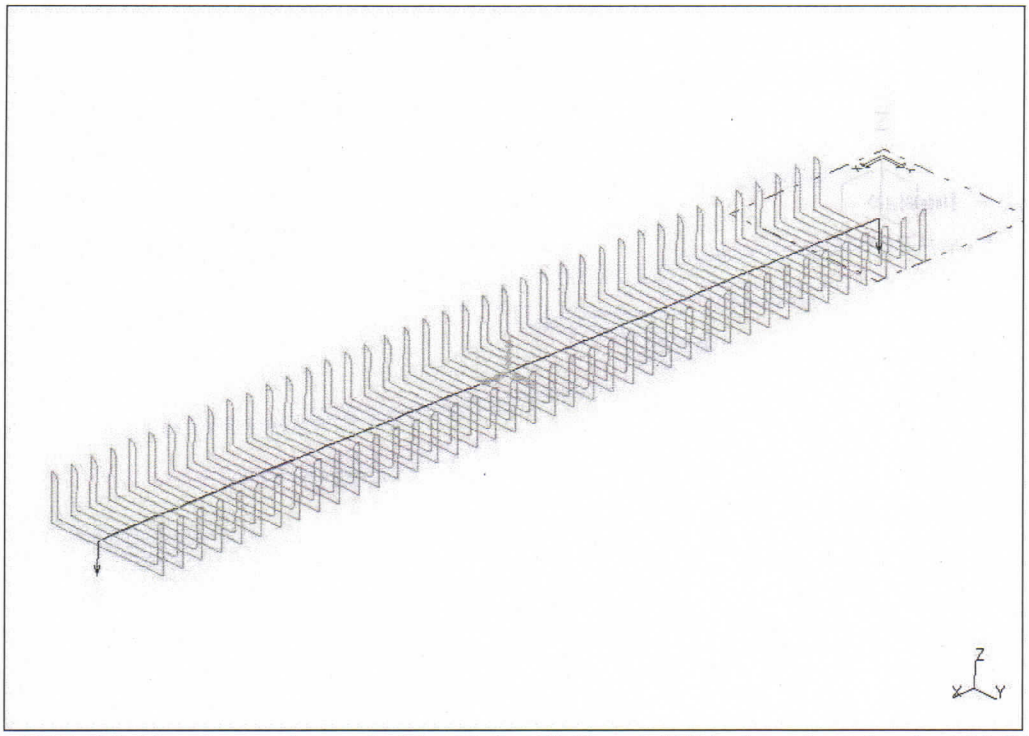

Figure 2. 6061 T6 Aluminum channel, 6" wide by 2¼" and 40" in length. A load of 81 Lbs is applied to both ends, the center fixed.

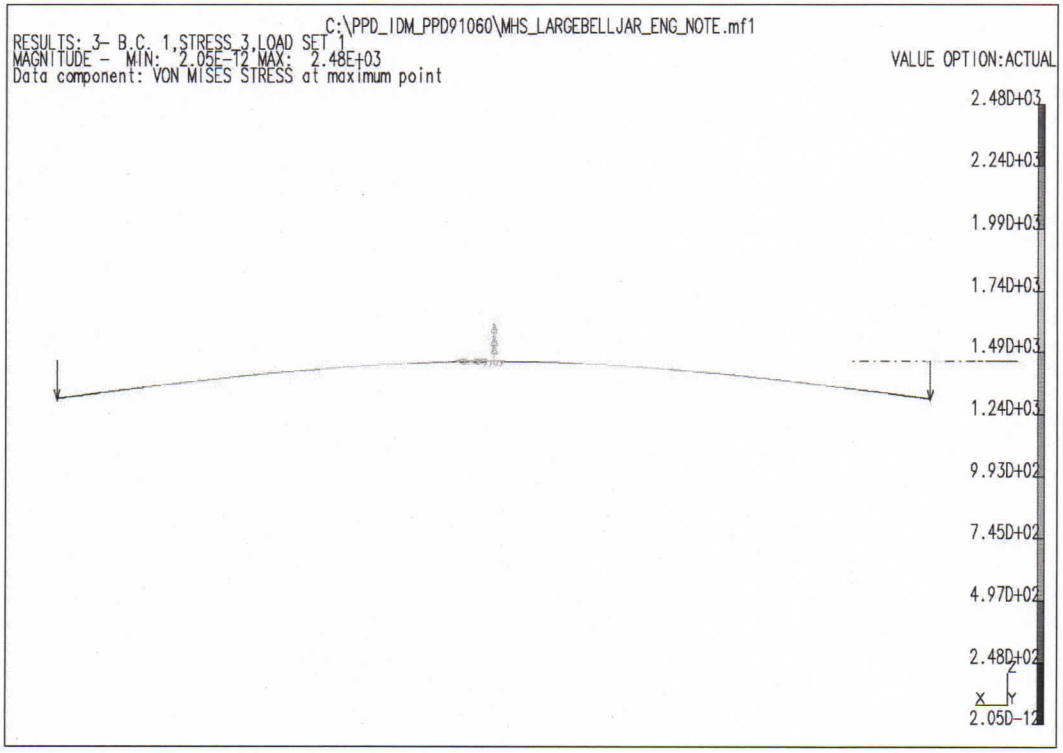

Figure 3. The max stress in the beam is 2480 psi, significantly lower than the allowable stress of 12,000 psi. End deflection is shown exaggerated, actual is .022".

Bolt hole bearing strength (channel)

$$Available bearing\ strength = \frac{R_n}{\Omega},\ \Omega = 2$$

$$R_n = 1.5 L_c t F_u \le 3.0 d t F_u$$

$$Eqn.\ J3-6b\ taken\ from\ AISC\ Steel\ Construction\ Manual$$

$$Where:$$

$$d = \tfrac{3}{8} = Nom.bolt\ diameter, in.$$

$$F_u = 12 = Tensile\ strength\ of\ material, ksi$$

$$L_c = \tfrac{9}{16} = Dist.\ from\ edge\ of\ beam, in.$$

$$t = .314 = Thickness\ of\ material, in.$$

$$R_n = 3.18 kips$$

$$Bearing\ strength = \frac{R_n}{2}$$

$$= 1.59 kips$$

$$= 1590 lbs$$

The 1590lb bearing strength of the bolt hole is extremely conservative, as it assumes an unlikely load path. The strength is more than sufficient for 130lb load of the collar.

Item (2) Stainless bolts

The block holding the collar acts like a third-class lever, and the bolt provides the effort to resist the weight of the collar. The effective load on the bolt is 4.5x weight of the collar, due the respective moment arms. Figure 4 illustrates this concept. In actuality, the bolts thread directly into the block (item 3 in figure 4), and would be preloaded to form a rigid connection.

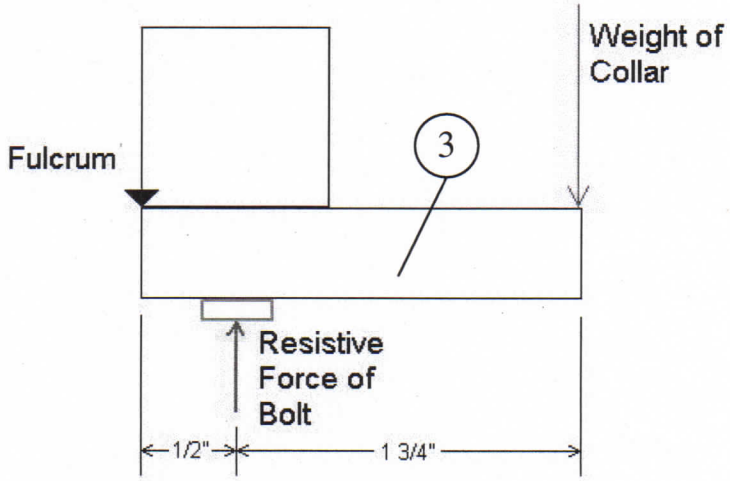

Figure 4. Shows the 3rd class lever.

Assuming one bolt carries a sixth of the total load, the tensile stress is:

$$\sigma_t = \frac{4.5P}{A_t} = \frac{4.5 * 27.3lbs}{.0775\,in^2}$$

$$\sigma_t = 1586\ psi$$

Where

$P = Load$

$A_t = Stress\ \ area\ \ of\ \ the\ \ bolt$

For the 3/8" eyebolt carrying the full load:

$$\sigma_t = \frac{P}{A_t} = \frac{162\,lbs}{.0775\,in^2}$$

$$\sigma_t = 2090\ psi$$

Where

$P = Load$

$A_t = Stress\ \ area\ \ of\ \ the\ \ bolt$

10,300 psi is the max allowable stress in the stainless bolts.

Item (3) 2 ¼" X ½" X 6" Aluminum block

Figure 4, item 3 above shows the loading of the aluminum block that holds the LBJ collar. This places ~81lb on the end of the block. The maximum moment occurs at the bolt. Sectioning the block into thirds, and assuming it acts like a beam, the max stress is as follows:

$$\frac{81 lbs}{3 bolts} = 27.3 lb\ load$$

$$95.6 lbs\ reaction\ to\ the\ load$$

$$95.6 lbs \times \tfrac{1}{2} in. = 47.8 lb \cdot in\ moment\ in\ beam$$

$$\sigma_m = \frac{|M|_{\max} c}{I} = \frac{47.8 lb \cdot in * .25 in}{.021 in^4}$$

$$\sigma_m = 570\ psi\ stress\ in\ the\ block$$

Where

$|M|_{\max}$ = *Max moment in beam*

c = *Dist. from neutral axis*

I = *Moment of inertia*

Conclusion

All stresses in the lifting device are less than the allowable stress in the materials. This satisfies the requirements of B30.20 that all Below-the-Hook Lifting Devices have a safety factor of 3 or greater. The device is sufficient to hold the load of the Large Bell Jar lower collar. Figure 5 shows the device under loaded with 165 Lbs during the lifting device rating test at 125%. The test was performed by John Voirin on 7/19/2007 and witnessed by Andrew Lathrop.

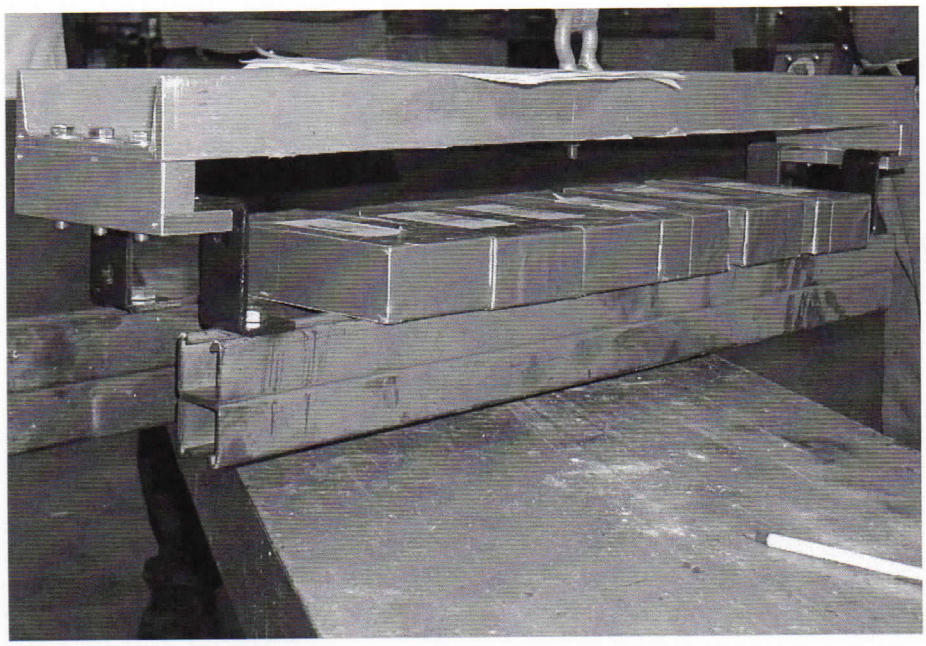

Figure 5. Large Bell Jar lifting fixture loaded 125% of the 130Lb rating.